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# (54) SINGLE-WIRE SPIRAL ANTENNA

(57) Taking the spiral circumference, C, of a single wire spiral antenna as 2.3 λ (λ being the wavelength at the operating frequency), for example, the beam radiated from an axis Z perpendicular to the antenna surface is tilted. The beam tilt angle changes with the spiral circumference, C, and the spiral circumference, C, is set to between 2 λ and 3 λ.

Fig. 1b

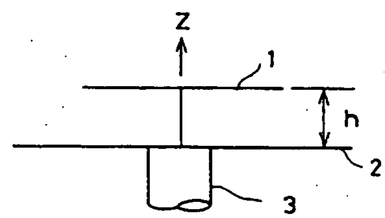
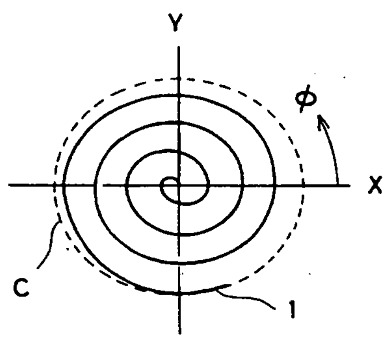



Fig. 1a




EP 0 825 674 A1

## Description

### TECHNICAL FIELD

The present invention relates to a spiral antenna constituted by a single wire, and more particularly, to a spiral antenna whereby a tilted beam can be formed.

### BACKGROUND ART

Communications using circular polarized waves are commonly conducted in the fields of mobile communications and satellite communications. Helical antennas and spiral antennas capable of transmitting and receiving circular polarized-waves are commonly employed in communications using these circular polarized waves.

A helical antenna has maximum directivity in the direction of its helical winding axis, whilst a primary mode spiral antenna has maximum directivity in a perpendicular direction to the antenna surface. A secondary mode spiral antenna has bidirectional radiation characteristics.

However, in the field of communications, there are cases where a particular communications direction is required, as in satellite communications. If there is a specific communications direction in this way, then the antenna beam must be set such that it matches the angle of elevation and the azimuth angle thereof.

Therefore, conventionally, the antenna is composed such that the angle of elevation of the antenna beam can be matched to the angle of elevation of the communications direction by inclining the antenna itself, and the antenna as a whole is rotatable such that when it is mounted in a mobile station, it can be aligned with the azimuth angle of the communications direction.

However, if the antenna itself is inclined such that the beam emitted from the antenna has a specific angle of elevation, then the surface area of the antenna exposed to the wind increases and it becomes necessary to strengthen the antenna fixing means. Moreover, the height of the antenna increases and there is a risk that it may exceed a maximum height when it is mounted in a mobile station.

Therefore, it is an object of the present invention to provided a single wire spiral antenna whereby the surface area of the antenna exposed to the wind can be reduced, the height of the device can be reduced, and the radiation beam of a circular polarized wave can be tilted.

### DISCLOSURE OF THE INVENTION

In order to achieve the aforementioned object, in the single wire spiral antenna of the present invention, a spiral antenna constituted by a single wire is positioned above the ground plane at a prescribed interval therefrom and, taking the wavelength used as L, the spiral circumference of said spiral antenna is set to between 2 $\lambda$ and 3 $\lambda$.

Furthermore, taking the wavelength used as $\lambda$, the spiral circumference of a spiral antenna element constituted by a single wire is set to between $2\lambda$ and $3\lambda$, and a plurality of said spiral antenna elements are positioned above a reflective plate at a prescribed interval therefrom.

In a single wire spiral antenna according to the present invention of this kind, it is possible to tilt a beam with respect to the axis perpendicular to the antenna surface, and by aligning the angle of elevation of the beam with the communications direction, the spiral antenna can be set up in a horizontal plane. Therefore, the set-up height of a spiral antenna capable of emitting a beam at a desired angle of elevation can be reduced, the surface area of the antenna exposed to wind can be reduced, and the antenna can be prevented from exceeding a height limit even when mounted in a mobile station.

Furthermore, even if an array of single wire spiral antennas of this kind is formed, a plurality of antennas should be arranged in a horizontal direction, so there is no increase in the set-up height of the spiral antenna.

### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is a top view showing the composition of a mode for implementing a single wire spiral antenna according to the present invention; and Fig. 1b is a side view of same;

Fig. 2 shows a radiation pattern in plane Y - Z of a single wire spiral antenna according to the present invention;

Fig. 3 shows a radiation pattern in plane X - Y of a single wire spiral antenna according to the present invention;

Fig. 4 shows a radiation pattern in plane X - Z' of a single wire spiral antenna according to the present invention;

Fig. 5 shows a three-dimensional view of a radiation pattern of a single wire spiral antenna according to the present invention;

Fig. 6 is a diagram for describing single wire spiral antennas according to the present invention formed into an array;

Fig. 7 shows the composition of single wire spiral antennas according to the present invention formed into an array;

Fig. 8a shows a radiation pattern in plane Y - Z of single wire spiral antennas according to the present invention formed into an array; and Fig. 8b shows a radiation pattern in plane X - Z' of same; and

Fig. 9 illustrates axial ratio and gain characteristics with respect to frequency for single wire spiral antennas according to the present invention formed into an array.

## BEST MODE FOR CARRYING OUT THE INVENTION

The composition of a mode for implementing a single wire spiral antenna according to the present invention is shown is Fig. 1a and Fig. 1b. Fig. 1a is a top view of a single wire spiral antenna and Fig. 1b is a side view of same.

As shown in these diagrams, a single wire spiral antenna 1 is positioned such that the antenna surface is parallel to a ground plane 2 and separated from the ground plane 2 by an interval h. The spiral circumference, C, of this single wire spiral antenna 1 is set, for example, to approximately 2.3 λ (λ being the wavelength at the operating frequency,) and the interval h between the ground plane 2 and the single wire spiral antenna 1 is set to approximately 1/4 λ.

A high-frequency signal of wavelength λ is supplied to the single wire spiral antenna 1 from a coaxial cable 3. The earth section of the coaxial cable 3 is connected to the ground plane 2, and the core wire is connected to the single wire spiral antenna 1.

Fig. 2 shows a radiation pattern in plane Y - Z of a single wire spiral antenna 1 constituted in this way, when the antenna surface of the single wire spiral antenna 1 is taken as plane X - Y and the direction perpendicular to the antenna surface is taken as the Z axis. This radiation pattern is for a plane where the angle, $\phi$, shown in Fig. 1a is 232°, and it can be seen that a fan beam having a beam tilt angle, $\theta$, of 28° is formed. In other words, the direction of maximum radiation of the single wire spiral antenna 1 is the direction $\phi$ = 232°, $\theta$ = 28°. The axial ratio in this case is a satisfactory figure of 1.9 dB and the gain is 8.2 dB.

In this way, the single wire spiral antenna 1 according to the present invention is able to form a fan beam which is tilted from the direction perpendicular to the antenna surface.

A radiation pattern in plane X - Y of the single wire spiral antenna 1 is shown in Fig. 3, but here the Z axis is inclined through the beam tilt angle ($\theta$ = 28°). From this radiation pattern also, it can be seen that the angle $\phi$ of the direction of maximum radiation is $\phi$ = 232°. Fig. 4 shows a radiation pattern in plane X - Z' of the single wire spiral antenna 1. This Z' axis represents an axis inclined through the beam tilt angle ($\theta$ = 28°).

Fig. 5 shows a three-dimensional view of a radiation pattern of a single wire spiral antenna 1.

If the spiral circumference C of the single wire spiral antenna 1 according to the present invention is between 2 λ and 3 λ, then it is possible to tilt the beam formed thereby. In this case, if the spiral circumference C is changed, the beam tilt angle, $\theta$, will also change. Furthermore, the interval h between the ground plate 2 and the single wire spiral antenna 1 is not limited to 1/4 λ, but it should be in the vicinity of 1/4 λ.

Moreover, whilst the single wire spiral antenna 1 can be formed from wire, it is also possible to form a single wire spiral antenna 1 onto a insulating film, and to fix the ground plate 2 and the single wire spiral antenna 1 together by means of a dielectric such as a foamed material, or the like, positioned therebetween.

Next, Fig. 7 shows the composition of a four-element array antenna using four single wire spiral antennas as illustrated in Fig. 1a and Fig. 1b.

In this diagram, 1-1 - 1-4 are single wire spiral antenna elements, which are arranged at an interval h above a reflector 4. In this case, the spacing d between the single wire spiral antenna elements 1-1 - 1-4 is set to approximately 0.8 λ, and the single wire spiral antenna elements 1-1 - 1-4 are rotated 218° to direction $\phi$ as shown in Fig. 6, such that the direction of maximum radiation of the antenna array is plane Y - Z. The interval h between the single wire spiral antenna elements 1-1 - 1-4 and the reflector 4 is set to approximately 1/4 λ.

Electricity is supplied to the single wire spiral antenna elements 1-1 - 1-4 by means of a coaxial cable omitted from the drawing, and the electricity supply is set such that all of the single wire spiral antenna elements 1-1 - 1-4 are in phase with each other.

Fig. 8 shows radiation patterns for an antenna array composed as shown in Fig. 7. Fig. 8a is a radiation pattern in plane Y - Z; the beam tilt angle, $\theta$, in the direction of maximum radiation is approximately 24°, which diverges by approximately 4° from the figure for an independent single wire spiral antenna element. Fig. 8b shows a radiation pattern in plane X - Z', and since the single wire spiral antenna elements 1-1 - 1-4 comprise an antenna array in a horizontal direction, the beam forms a pencil beam in the direction of the azimuth angle. The Z' axis is an axis inclined through the beam tilt angle ($\theta$ = 24°) from the Z axis.

Fig. 9 shows axial ratio and gain characteristics with respect to frequency for an antenna array constituted as shown in Fig. 7. As illustrated in this diagram, the axial ratio is a satisfactory figure of 3 dB or less across a wide frequency band from approximately 5.7 GHz to approximately 7 GHz. Furthermore, the gain is also high with a maximum gain figure of 14.7 dB, and high gain can be obtained across a wide frequency band. In particular, when the operating frequency band is taken as 5.5 GHz - 7.0 GHz, the frequency bandwidth where the axial ratio is 3 dB or less with respect to the centre frequency thereof is a broad bandwidth of approximately 22%.

The spiral circumference C of each single wire spiral antenna element 1-1 - 1-4 constituting the antenna array exceeds 2 λ but is less than 3 λ. In this case, if the spiral circumference C is changed, the beam tilt angle, $\theta$, also changes. Therefore, the beam from the single wire spiral antenna 1 can be aligned with the communications direction by changing the spiral circumference C.

The interval h between the reflector 4 and the single wire spiral antenna elements 1-1 - 1-4 is not limited to 1/4 λ, but it should be in the region of 1/4 λ. The spacing, d, between the single wire spiral antenna elements

1-1 - 1-4 is not limited to approximately 0.8 111, but it should be set such that the side lobes of the antenna array are optimized.

Moreover, as shown in Fig. 7, a space having a dielectric constant $\varepsilon_r = 1$ (vacuum) is formed between the reflector 4 and the single wire spiral antenna elements 1-1 - 1-4, but it is also possible for the reflector 4 and the single wire spiral antenna elements 1-1 - 1-4 to be fixed together by means of a dielectric such as a foamed material, or the like, positioned therebetween. In this case, it is preferable for the single wire spiral antenna elements 1-1 - 1-4 to be formed onto an insulating film.

As described above, since it is possible to tilt the beam of the single wire spiral antenna according to the present invention, it is able to form a low-profile antenna when mounted in a mobile station. Therefore, the antenna can be installed readily, and its structure is also simplified. Furthermore, since the single wire spiral antenna according to the present invention has an electricity supply point in the centre of the antenna, even if the antenna is rotated within a horizontal plane, no irregularity in rotation occurs.

When antennas according to the present invention are formed into an array, the size of the antenna system increases only in a horizontal direction, and therefore such an array can be used satisfactorily even when there are restrictions in the height direction.

The frequencies cited in the description above are examples of the operating frequency of a single wire spiral antenna according to the present invention, but the device is not limited to these frequencies.

## INDUSTRIAL APPLICABILITY

Since the present invention is constituted as described above, a beam can be tilted in the direction of the angle of elevation, and therefore the angle of elevation of the beam can be aligned with the communications direction, and the spiral antenna can be set up in a horizontal plane. Consequently, the set-up height of a spiral antenna whose beam is directed in a desired direction can be reduced, the surface area of the antenna exposed to wind can be reduced, and it is possible to prevent the antenna from exceeding a height limit, even when it is mounted in a mobile station.

When single wire spiral antennas of this kind are arrayed, a plurality thereof should be arrayed in a horizontal direction, such that there is no increase in the set-up height of the spiral antenna. Thereby, it is possible to prevent the antenna from exceeding height limits.

## Claims

1. A single wire spiral antenna characterized in that a spiral antenna positioned above a ground plane at a prescribed interval therefrom is constituted by a single wire and, taking the wavelength used as $\lambda$, the spiral circumference of said spiral antenna is set to a length between 2 $\lambda$ and 3 $\lambda$.

2. A single wire spiral antenna characterized in that, taking the wavelength used as $\lambda$, the spiral circumference of a spiral antenna element constituted by a single wire is set to a length between 2 $\lambda$ and 3 $\lambda$, and a plurality of said spiral antenna elements are positioned above a reflector plate at a prescribed interval therefrom.

Fig. 1a

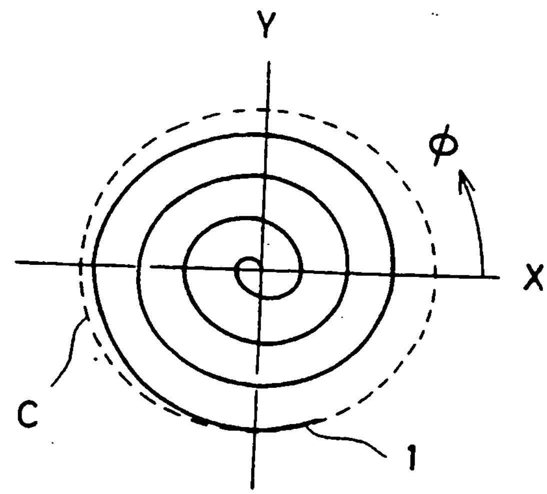



Fig. 1b

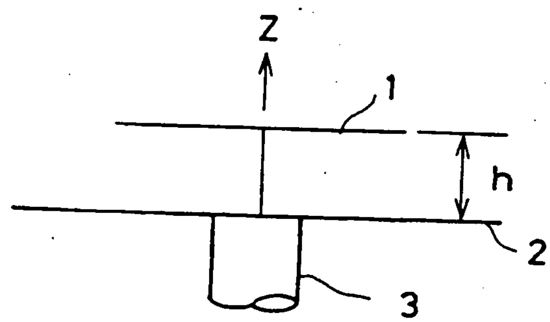
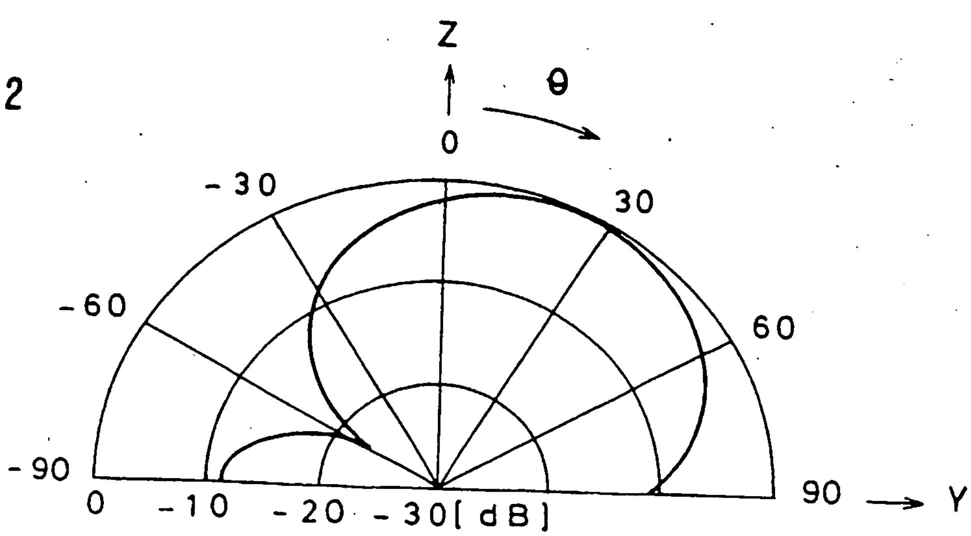



Fig. 2




$\phi = 232^{\circ} \quad (= \phi_m)$ Plane

Fig. 3

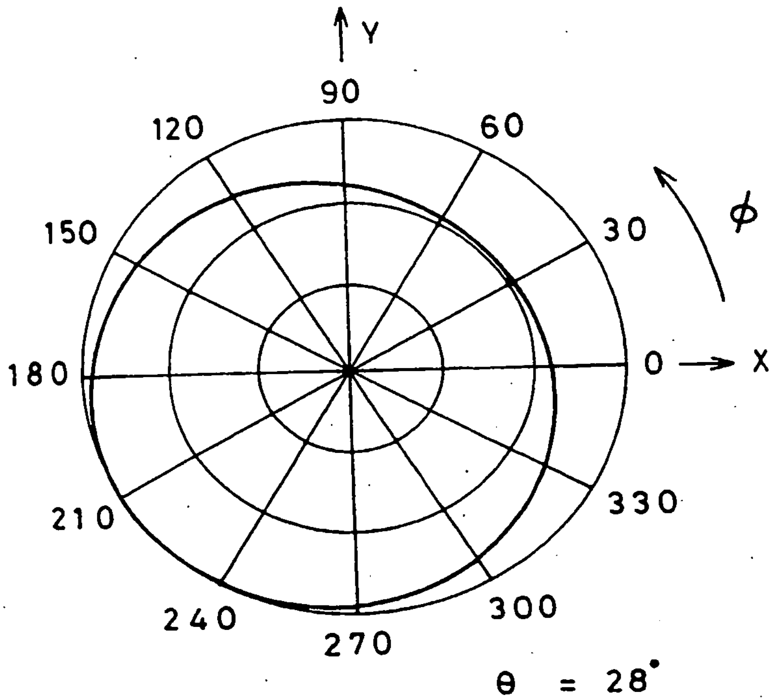

Y
90
120
60
150
30
φ
180
0
X
210
330
240
300
270
θ = 28°

Fig. 4

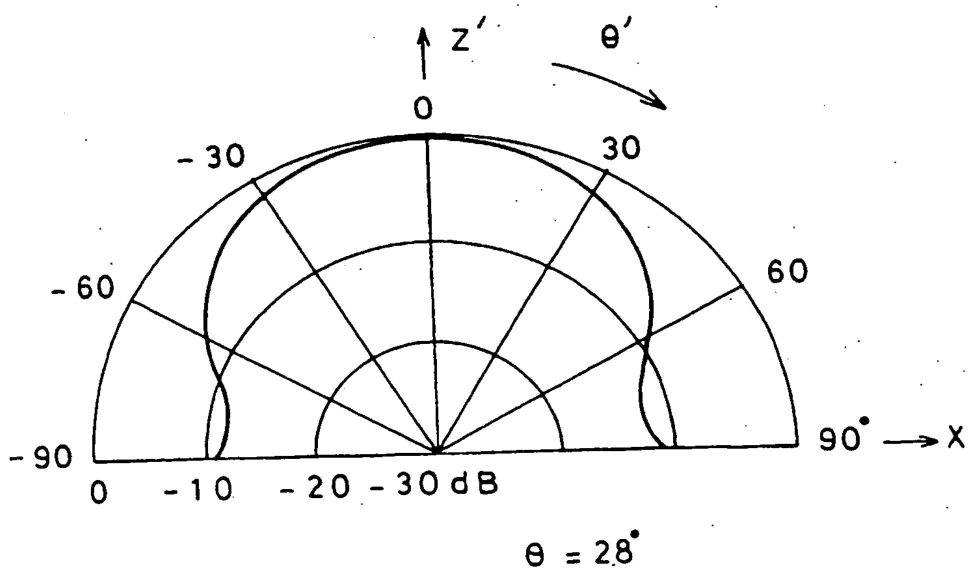

Z′
θ′
0
-30
30
-60
60
-90
90°
X
0
-10
-20
-30 dB
θ = 28°

Fig. 5

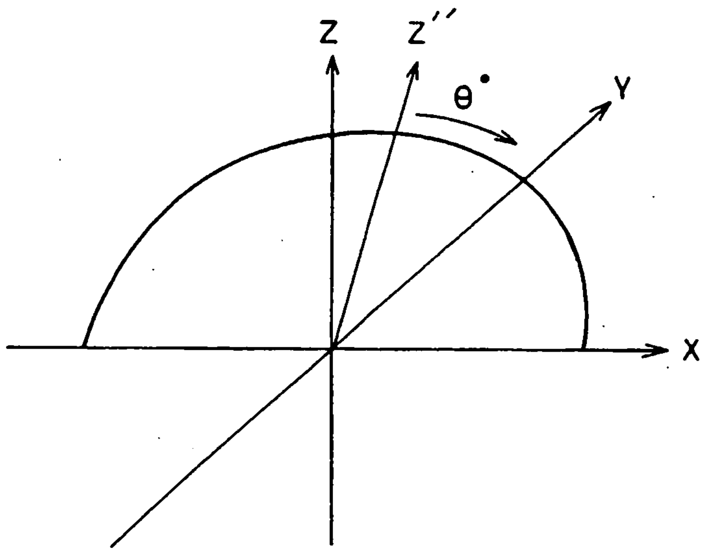



Fig. 6

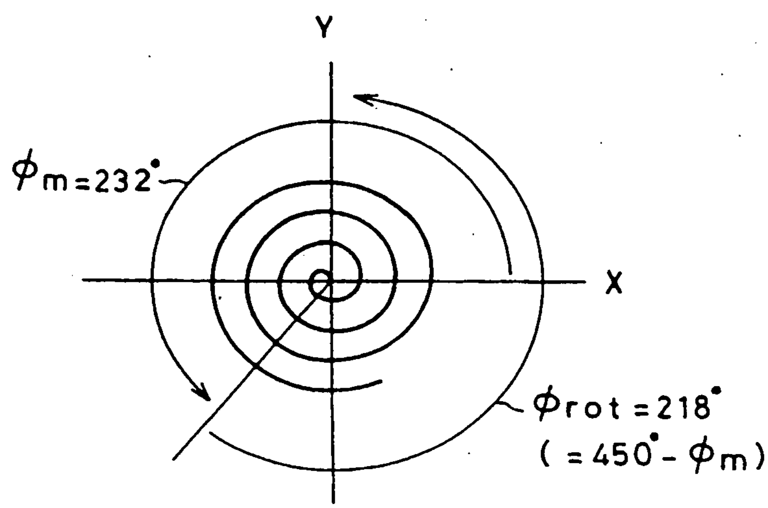


Fig. 7

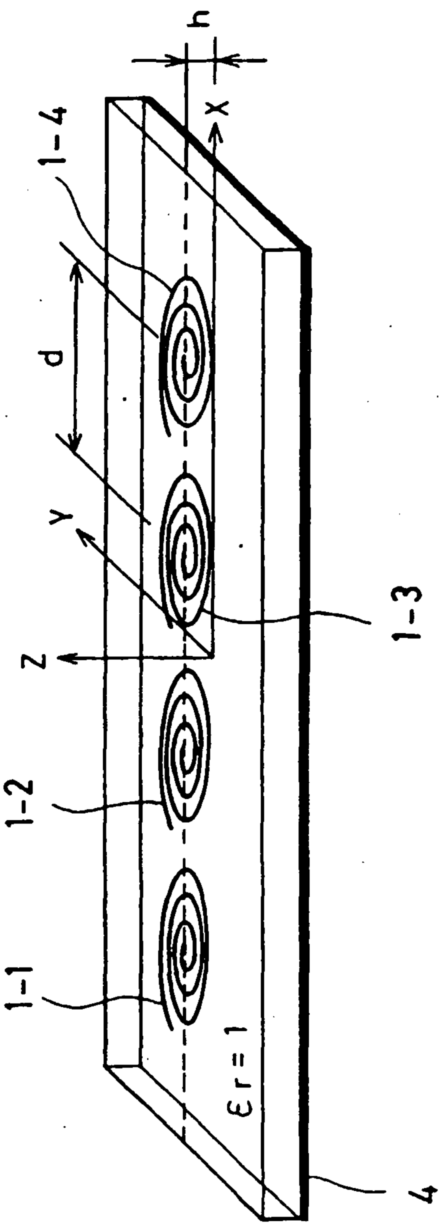
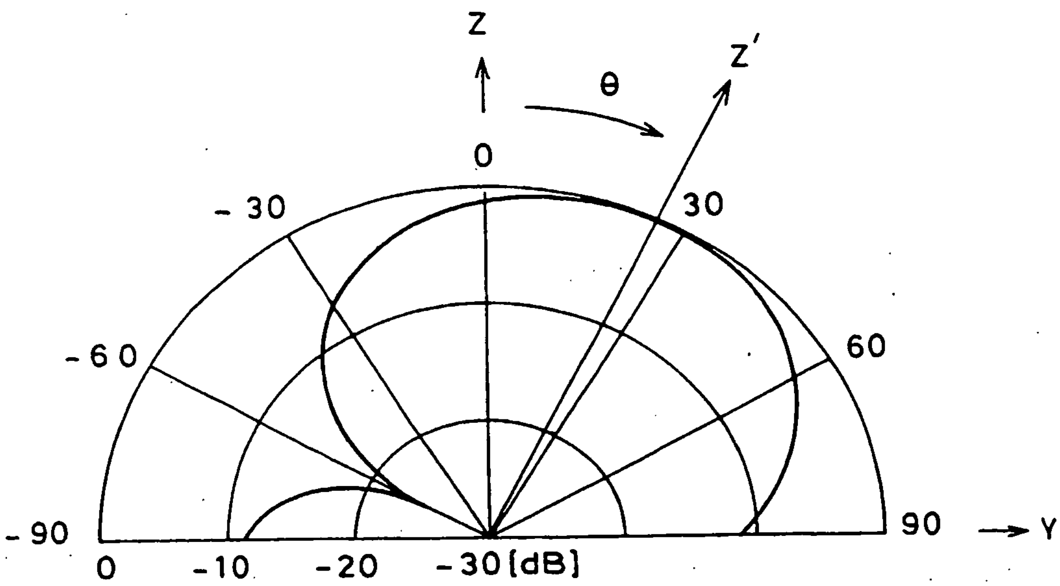
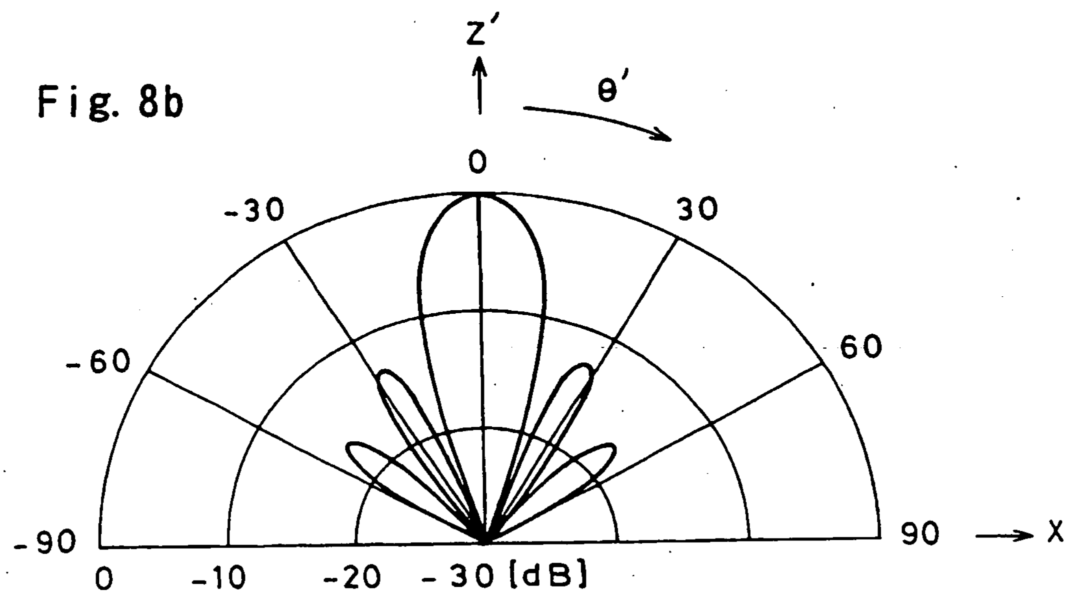


Fig. 8a



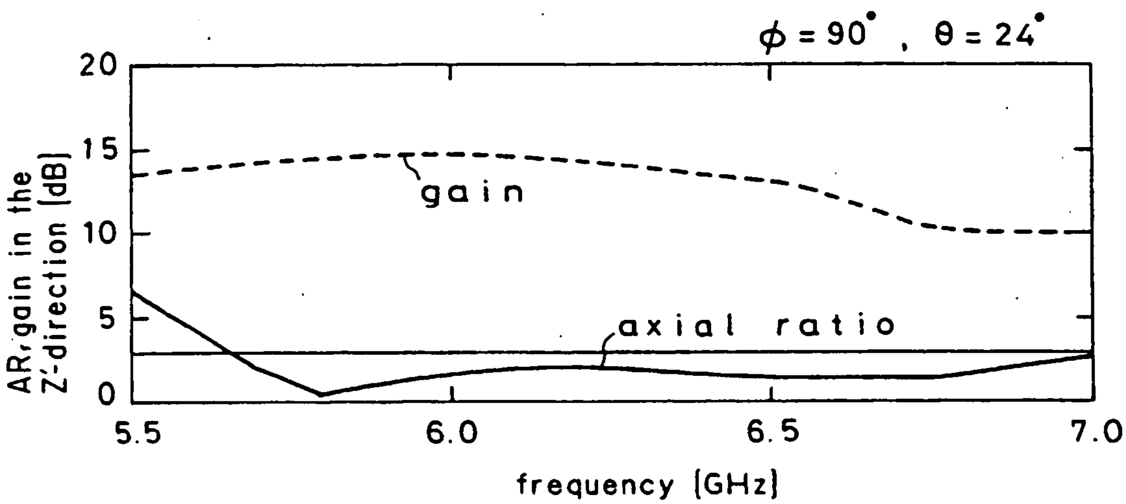

$\phi$ = 90° (Y-Z) Plane

Fig. 8b




X-Z' Plane

Fig. 9




Axial ratio and gain vs. frequency

## INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP97/00511

**A. CLASSIFICATION OF SUBJECT MATTER**

Int. Cl[6] H01Q9/27, H01Q21/08

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl[6] H01Q9/27, H01Q21/08

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho 1926 - 1997
Kokai Jitsuyo Shinan Koho 1971 - 1997
Toroku Jitsuyo Shinan Koho 1994 - 1997
Jitsuyo Shinan Toroku Koho 1996 - 1997

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

| Category* | Citation of document, with indication, where appropriate, of the relevant passages | Relevant to claim No. |
|---|---|---|
| A | Microfilm of the specification and drawings annexed to the written application of Japanese Utility Model Application No. 87612/1992 (Laid-open No. 48209/1994) (Yokowo Co., Ltd.), June 28, 1994 (28. 06. 94), Claim 1 (Family: none) | 1, 2 |
| A | JP, 4-281604, A (Nihon Dengyo Kosaku Co., Ltd.), October 7, 1992 (07. 10. 92), Claim 1 (Family: none) | 1, 2 |
| A | JP, 62-216407, A (Nihon Dengyo Kosaku Co., Ltd.), September 24, 1987 (24. 09. 87), Claim 1 (Family: none) | 1, 2 |
| A | JP, 58-134511, A (Mitsubishi Electric Corp.), August 10, 1983 (10. 08. 83), Claim (Family: none) | 2 |

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
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"&" document member of the same patent family

| Date of the actual completion of the international search | Date of mailing of the international search report |
|---|---|
| May 19, 1997 (19. 05. 97) | May 27, 1997 (27. 05. 97) |

| Name and mailing address of the ISA/ | Authorized officer |
|---|---|
| Japanese Patent Office | |
| Facsimile No. | Telephone No. |

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